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The Effectiveness of Diflubenzuron and Fenitrothion Against the Eastern Hemlock Looper, *Lambdina Fiscellaria Fiscellaria*, in Newfoundland in 1986.

A. G. Raske and A. Retnakaran

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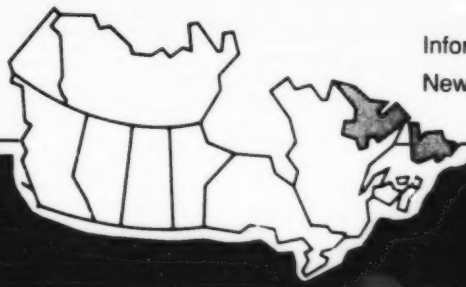

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THE EFFECTIVENESS OF DIFLUBENZURON AND FENITROTHION AGAINST THE EASTERN HEMLOCK LOOPER, *LAMBDINA FISCELLARIA FISCELLARIA*, IN NEWFOUNDLAND IN 1986.

by A.G. Raske and A. Retnakaran

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FOREWORD

The experimental sprays in 1986 in Newfoundland were a joint research effort by the Forest Protection Division of the Newfoundland Department of Forest Resources and Lands and the Newfoundland Forestry Centre and the Forest Pest Management Institute of the Canadian Forestry Service. Funding was provided by the Province through the Federal-Provincial Forestry Agreements and the Canadian Forestry Service, supplemented by contributions from Sumitomo Chemical America, Inc. and Duphar B.V. of Holland.

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ABSTRACT

An insect growth regulator, diflubenzuron, and an organophosphorous insecticide, fenitrothion, were tested against the eastern hemlock looper, Lambdina fiscellaria fiscellaria, in western Newfoundland in July 1986. A 25 percent wettable powder formulation of diflubenzuron (Dimilin 25 wp®) was sprayed at the rates of 70 g ai/ha in 2.5 ℓ of water/ha and 70 g ai/ha in 4.7 ℓ of water/ha. A flowable formulation of fenitrothion (Sumithion 20F®) sprayed at the rate of 180 g ai/ha in 0.9 ℓ of water/ha and was compared to fenitrothion (Folethion Technical®) sprayed at 210 g ai/ha in 1.5 ℓ of stove oil/ha. Each treatment was sprayed twice near optimal weather conditions.

The population reduction at the larval stage was 26% for diflubenzuron in 2.5 ℓ/ha; and 62% for diflubenzuron in 4.7 ℓ/ha. Reduction for fenitrothion at 180 g was 54% and 65% for fenitrothion technical at 210 g. At the pupal stage population reduction was 90, 93, 92 and 99% respectively. Moth emergence was reduced to 7% for diflubenzuron at 2.5 ℓ/ha, 18% for diflubenzuron at 4.7 ℓ/ha and unaffected for the two fenitrothion treatments.

Foliage protection was 0% for diflubenzuron at 2.5 ℓ/ha and 40% in diflubenzuron at 4.7 ℓ/ha. Fenitrothion spray provided 65% foliage protection for the flowable formulation and 59% for the Technical.

The more concentrated formulation of diflubenzuron, 70 g ai/ha at 2.5 ℓ/ha, provided population reduction at moth emergence as great as the standard concentration. However, mortality occurred later in the insect life history and foliage protection was not achieved for the concentrated formulation. Earlier application of diflubenzuron should be tested.

The lower dose of fenitrothion at 180 g ai/ha caused slightly less population reduction than the operational dose of 210 g ai/ha. However, foliage protection was essentially the same because larval mortality in both treatments occurred at the same time. High humidity while spraying the flowable formulation provided good deposit. This may not always occur during operational sprays and the flowable formulation may not be a substitute for the oil-base spray of fenitrothion especially for large aircraft which fly higher above the canopy than do small aircraft. Fenitrothion was tested at 140 ai/ha in 1985 and provided inadequate larval reduction. Therefore, a dose of 180 g ai/ha may be close to the lower limit that will provide adequate control. Earlier application may increase the degree of foliage protection.

RÉSUMÉ

En juillet 1986, les auteurs ont procédé à des essais avec le diflubenzuron, un régulateur de croissance des insectes, et le fenitrothion, un organophosphorous, pour lutter contre l'arpenteuse de la pruche (Lambdina fiscellaria fiscellaria) dans l'ouest de Terre-Neuve. Ils ont pulvérisé une préparation de poudre mouillable de Dimilin® à 25% à une dose de 70 g d'ingrédient actif diluée dans 2,5 L d'eau par hectare et comparé son efficacité à celle d'une dose de 70 g diluée dans 4,7 L d'eau par hectare. Une préparation fluidifiable de Sumithion 20F® pulvérisée à une dose de 180 g diluée dans 0,9 L d'eau par hectare a été comparée à une dose de 210 g de Folethion Technical® diluée dans 1,5 L de mazout par hectare. Chaque traitement a été répété à deux reprises dans des conditions météorologiques presque optimales.

Le Dimilin dilué dans 2,5 L/ha a entraîné une diminution de 26% des populations larvaires et de 62% lorsque dilué dans 4,7 L/ha. Le Sumithion 20F a provoqué une diminution de 54% et le fenitrothion technical de 65%. Au stade de chrysalide, la diminution des populations atteignait respectivement 90, 93, 92 et 99%. Le Dimilin dilué dans 2,5 L/ha a fait chuter le pourcentage d'émergence des papillons à 7% comparativement à 18% pour le Dimilin dilué dans 4,7 L/ha, tandis que les traitements au Sumithion n'ont eu aucun effet.

Le Dimilin dilué dans 2,5 L/ha n'a assuré aucune protection (0%) du feuillage comparativement à 40% lorsque dilué dans 4,7 L/ha. Le traitement au Sumithion sous forme fluidifiable a protégé le feuillage à 65% et le Technical à 59%.

La préparation plus concentrée de Dimilin, soit 70 g/ha d'ingrédient actif dilué dans 2,5 L/ha a entraîné une diminution des populations émergentes de papillons aussi importante que la dose habituelle. La mortalité a toutefois été observée plus tard au cours du cycle évolutif de l'insecte et la formulation concentrée n'a pas assuré la protection du feuillage. Il faudrait tenter d'appliquer du Dimilin plus tôt en saison.

La moindre dose de fenitrothion (180 g/ha d'ingrédient actif) a provoqué une réduction des populations plus faible que la dose habituelle de 210 g/ha. Le degré de protection du feuillage était toutefois fondamentalement le même car la mortalité des larves s'est produite en même temps au cours des eux traitements. La forte humidité qui régnait au moment de la pulvérisation de la préparation fluidifiable a favorisé son dépôt. De telles conditions ne se présenteront pas toujours lors des opérations de pulvérisation et la préparation fluidifiable peut ne pas être un bon substitut au fenitrothion en solution huileuse, notamment lorsque la pulvérisation est effectuée par un avion plus gros qui doit survoler à plus haute altitude le couvert forestier. En 1985, le fenitrothion a été testé à une dose de 140 g/ha d'ingrédient actif mais n'a pas entraîné de réduction suffisante des populations larvaires. Par conséquent, une dose de 180 g/ha pourrait bien être la dose minimale permettant de réprimer adéquatement cet insecte. Un traitement effectué plus tôt en saison peut accroître le degré de protection du feuillage.

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by

A.G. Raske and A. Retnakaran

INTRODUCTION

The eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.), has been an important pest of balsam fir, *Abies balsamea* (L.) Mill., in Newfoundland since at least the turn of the century (Carroll 1956). This insect has reached outbreak levels at least six times since 1912 and caused tree mortality in areas throughout the Island (Otvos *et al.* 1979). The most recent outbreak, lasting from 1967 to 1971, was the largest and caused an estimated 12 000 000 m^3 volume of balsam fir to die (Otvos *et al.* 1979). Details of the life history of the looper, its impact in Newfoundland and past attempts to control the insect have been reviewed (Raske *et al.* 1986).

The current outbreak started in 1983 in two widely separated areas of Newfoundland and resulted in almost 10 000 ha of severe defoliation. The areas of moderate and severe defoliation were 53 000 ha in 1984 (Clarke and Carew 1985), 52 000 ha in 1985 (Clarke and Carew 1986) and 215 000 ha in 1986 (Clarke and Carew 1987). The outbreak was concentrated in western Newfoundland and extended into central Newfoundland to Red Indian Lake and Victoria Lake (Fig. 1). Other areas of defoliation occurred around Terra Nova National Park and Deer Lake. Several patches of land on the Avalon Peninsula were also defoliated.

In 1985 the Newfoundland Department of Forest Resources and Lands used fenitrothion to treat 122 700 ha and Bacillus thuringiensis (= B.t.) to treat 2 300 ha (Crummey 1986). In 1986 a total of 79 028 ha were sprayed with fenitrothion and 5420 ha with B.t. (Crummey 1987).

Experimental aerial applications were tried in 1985 testing various formulations of B.t., Dimilin 25WP® (= diflubenzuron), Sumithion 20F and Sumithion Technical® (= fenitrothion), and Matacil 180F® (= aminocarb) for efficacy against the hemlock looper in Newfoundland (Raske et al. 1986). Two applications of the B.t. formulation Thuricide 64B® at 30 BIU/ha gave nearly 100% larval reductions of late-instar larvae (West et al. 1987). Two applications of Thuricide 48LV® at 30 BIU/ha provided 34% larval and 82% pupal reduction. The results of Futura® at 30 BIU approximated those of Thuricide 48LV and Futura at 20 BIU/ha gave no control. All of these B.t. formulations were applied in July and provided little foliage protection. A double application of Dimilin at 70 g ai/ha in 4.7 ℓ/ha effectively controlled the looper but foliage protection was inadequate. The large population reduction which occurred at this dose in the treatment block contrasted sharply to that in the control block and to that in adjacent untreated areas. A single application of this dose reduced looper numbers only at the pupal stage and it may not be an acceptable dose for foliage protection. Dosages of 30 and 35 g ai/ha did not control the looper.

Water-based formulations of fenitrothion provided only partial control at the dosages of 140 and 210 g ai/ha. The registered dosage of

2 x 210 g ai/ha was less effective than Thuricide 64B at 30 BIU/ha and diflubenzuron at 2 x 70' g ai/ha.

Aminocarb was not effective against the looper even at 2 x 180 g ai/ha; twice the maximum dosage registered for spruce budworm control. This ineffectiveness against the hemlock looper was in agreement with unpublished laboratory investigations.

Spray droplet characteristics were analyzed for most formulations used in 1985. Diflubenzuron arrived at the canopy in larger proportion of small droplets than did the B.t. formulations (Sundaram et al. 1987a). However diflubenzuron sprays also formed a few undesirable large droplets that contained relatively large proportions of spray volume. The B.t. formulations had narrow droplet spectra and most of the spray volume arrived at the canopy in the desired droplet diameter range of 70 µm to 100 µm. Sumithion 20F arrived at the canopy with droplet spectra very similar to those of the B.t. formulations, but most droplets of Matacil 180F were too small to effectively impinge on the foliage (Sundaram et al. 1987b). Foliage deposits of Sumithion 20F were six to eight times greater than those of Matacil 180F.

Based on the 1985 results it was decided to test a more concentrated formulation of diflubenzuron as well as a new waterbase flowable formulation of fenitrothion (Sumithion 20F®) at 180 g ai/ha. Spraying earlier in the life cycle of the hemlock looper might provide better foliage protection and this was planned. Results of these experiments are here reported.

MATERIALS AND METHODS

Location and Experimental Design

The insecticides were tested near the town of Gallants in western Newfoundland, an area bounded by 58°14'-16'W longitude and 48°43'-45'N latitude (Fig. 2). Results of egg surveys in the fall of 1985 and in May 1986 were used to locate four treatment and three control blocks within this area. The terrain consisted of a small river valley sloping up to a generally flat plateau. The stands were almost pure balsam fir with widely scattered trees of white spruce, Picea glauca (Moench) Voss., and white birch, Betula papyrifera Marsh. The site is classified as "good" in the provincial forest inventory system of classification (Delaney and Osmond 1976).

Trees on all but one block were 8 m to 12 m in height and were 40 to 50 years old. The stands had originated after logging operations. Trees on one block were 6 m to 15 m in height and mature trees were generally over 80 years old. This stand was less dense, contained trees of all ages and was never logged.

Blocks treated with fenitrothion were 30 ha in area and measured 300 m by 1000 m and blocks treated with diflubenzuron were 51 ha in area and measured 240 m by 2120 m (Fig. 3). The blocks were bisected by a 3 m to 5 m wide transect formed by an existing forest road or, in one block, a strip cleared for an intended roadway. All transects did not need additional clearing of overhanging branches. These transects were used to enable the ground crew to guide the spray aircraft with a helium-filled balloon of 70 cm to 80 cm diameter.

Trees sampled to determine looper populations and foliage deposit, were chosen near the transects, with equal number of sample trees on each side. All sample trees were at least 60 m from the block edges (Fig. 4).

Three areas were designated as control blocks. These were not surveyed in a rectangular configuration.

Aircraft Parameters

All treatments were applied by a Grumman AgCat aircraft equipped with six AU-5000 Micronair spray units (Micronair, Aerial Ltd., Sandown, Isle of Wight, England) (Fig. 5). The flow rate was calibrated to deliver the desired volume in 30 m swath widths, while flying at a speed of 160 km/h and about 20 m above the tree canopy.

Diflubenzuron was sprayed before fenitrothion, and lower concentrations of material were sprayed before higher concentrations. Tanks in the airplane, booms and Micronairs were thoroughly washed between sprays. The Stephenville airport used for mixing and loading the aircraft was 30 km from the treated plots.

Communications

A radio-telephone network maintained contact during spray operations between the airport, the spray aircraft and mobile ground stations in the experimental plots.

Assessing Insect Numbers

Larval sampling was done by dislodging larvae from sample trees onto a 2.3 m by 3 m cloth placed beneath each tree. Larvae were dislodged by striking the branches on one side of the tree downward with

a 3 m long pole and counting the larvae that had fallen onto the cloth (Fig. 6). Trees were marked after sampling and were not resampled. The decision of when to spray was based on looper development monitored in the control blocks.

Pre-spray larval samples were taken within 24 hours prior to spray. Post-spray larval samples were taken 72 hours after the last application or as soon thereafter when weather permitted. Ten trees were sampled in control blocks at each sampling date and 2 sets of 10 trees in each treatment block to estimate treatment efficacy within that spray block (Fleming and Retnakaran 1985).

At each sample date 100 larvae from each block were retained for rearing to determine percent parasitism and disease. These larvae were reared individually in 50 ml plastic containers (Fig. 7). Post-spray samples of diflubenzuron-treated larvae were fed foliage collected from their respective blocks to reflect approximate proportional mortality of larvae in the diflubenzuron spray blocks.

The number of looper larvae surviving to pupation was determined with the use of pupal traps (Otvos 1974). Pieces of burlap 90 cm long were folded and wrapped around the bole about 1.5 m from the ground and stapled to the tree (Fig. 8). Sample size was 20 trees in the control blocks and two sets of 20 trees in each treatment block. Traps were placed on July 31 and August 2 and collected on August 21, 22 when larvae no longer occurred in the crowns. The number of living pupae were then counted. Dead larvae and pupae in the traps were examined for disease and parasitism.

Spray Application

Two applications at five day intervals were planned for the treatments because the hatching period is usually prolonged. The first spray of diflubenzuron was to be applied at early second instar larval stage and the second spray at late second instar. The first spray of fenitrothion was to be applied at peak second instar.

Insecticide Formulations and Tank Mixes

The insecticides and their formulations tested are listed in Table 1. The two diflubenzuron sprays were applied as water-based formulations (prepared from 25% wettable powder) adding only the dye Rhodamine B at a concentration of 1% by volume (Table 1). The flowable formulation of fenitrothion (Sumithion 20F) was applied as a water-based formulation with the same dye at 1%. The oil-base formulations of this chemical (Folethion Technical) was applied with 1% concentration of the dye Automate Red B.

Meteorological Monitoring

Weather conditions during the spray were monitored at a station situated among the spray blocks (Fig. 2). Wind speed and direction, and temperature at 1.5 m and at 13 m above ground were measured. The latter was used to determine the temperature gradient. If the upper temperature was equal to or higher than the lower temperature then conditions were good for spraying. However, if the lower temperature was higher than the upper, then the inversion had lapsed and the blocks were not sprayed. A Heathkit weather computer (Model I.D. 40001) was used and the displays were manually recorded at five minute intervals beginning before the

spray and continuing for 15 minutes after. Relative humidity was recorded with a portable hydrothermograph set inside a Stephenson Screen. Rainfall at the weather station was recorded at 24 hr intervals. Weather records were supplemented by field observations.

Spray Assessment

Spray deposits were monitored at ground level with units comprised of a 10 x 10 cm Kromekote® card and two 5.0 x 7.5 cm glass plates as described by Randall (1980). Ground units were placed in the treatment blocks less than 30 minutes before a spray and retrieved 30 to 60 minutes after. Units were placed at 15 m intervals along the transect and extended 45 m beyond each boundary. Mid-crown foliage was collected immediately after the spray to estimate foliage deposit.

Assessing Spray Results

The percent population reductions in the treatment blocks were corrected for natural mortality with Abbott's formula (Abbott 1925) as follows:

$$\% \text{ Population reduction} = 1 - \left[\frac{\text{Post-spray pop. in treatment}}{\text{Pre-spray pop. in treatment}} \times \frac{\text{Pre-spray pop. in control}}{\text{Post-spray pop. in control}} \right] \times 100$$

Treatment blocks were matched with control plots with similar pre-spray populations. Proportion of diseased larvae was determined from laboratory rearings.

Defoliation was assessed in two ways; by ground observation and by aerial estimation. Whole tree estimates from the ground were used because this method is more suitable to estimate looper defoliation. Defoliation percent was classed to the nearest 10% unit. Foliage protection was calculated as follows:

$$\text{Fol. Prot.} = \frac{\text{Defoliation Control - Defoliation Treatment}}{\text{Defoliation in Control}}$$

Aerial estimates of defoliation were made from a helicopter from an altitude of about 100 to 150 m above tree top and grouped into classes of Nil, Light, Moderate and Severe.

RESULTS AND DISCUSSION

Spraying Operations

Spray planes could not be obtained in time for the early applications planned. Therefore spraying took place as soon as the planes became available and as soon as weather permitted. At the time of the first spray about 80% of the larvae were in the second instar and the remainder in the first (Table 2). At the time of the second spray about 7% of the larvae were in the first instar, 53% in the second and 40% in the third.

Of the eight applications only two were morning sprays; the first application of each fenitrothion spray (Table 3). However,

relative humidity was 85% or above for all sprays, therefore evaporation of spray droplets was well within acceptable limits. Weather at the time of spray was ideal for all eight applications except for the first few swaths of the first application of diflubenzuron at 4.7 ℓ/ha (Table 3). Here, as the plane began spraying several gusts of wind blew at right angles to the flight lines and the spray cloud did not reach the first 60 m of the plot. This did not affect the trees sampled for population reduction. Temperatures were remarkably uniform for the eight applications. A rain-free period of 24 hours after a spray is desirable to enable the insecticide to dry on the foliage. There was a rain-free period for all applications of at least 20 hours (Fig. 10). However, a light drizzle, but no measurable precipitation started 12 hours after two of the sprays (Table 3). This drizzle was unlikely to have had a measurable affect on the treatments.

Spray deposit on Kromekote cards in diflubenzuron-treated blocks was very poor or non-existent. The reason for the lack of poor deposit at ground level is not known. Reasonable good deposit must have occurred in the canopy because population reduction occurred in both treated blocks. Spray droplets on Kromekote cards in fenitrothion-treated blocks formed streaks and bled into the surrounding tissue. Therefore, meaningful droplet data could not be obtained from the Kromekote cards of both insecticides sprayed. Spray deposits on foliage were not measured because freezer breakdown ruined the samples.

Population Reduction

Hemlock looper larval mortality by disease was not a factor in any block except one control block. In this control block the larvae stripped the trees of foliage and then fed on shrubs. Very few larvae were left to pupate in our pupal traps. Therefore this block was not used for comparison with treatment blocks. Efficacy data of all treatment blocks did not need adjusting for mortality caused by disease. Parasites of looper larvae and pupae were rare in all samples, and did not influence reduction estimates.

Larval reduction in diflubenzuron-treated blocks was sampled eight and nine days after the second treatment. Populations were reduced by 62% for the standard concentration of 70 g ai/ha in 4.7 ℓ/ha but only 26% for the higher concentration of 70 g ai/ha in 2.5 ℓ/ha (Table 4). In both blocks many larvae were still alive at the post-spray sample but died later while attempting to molt to the pupal stage. Population reduction at this time reached 90% and 93% respectively. Mortality continued into the adult stage and less than 20% of the pupae produced adults (Table 4). Final looper mortality was about the same in both blocks but mortality occurred sooner when diflubenzuron was applied in 4.7 ℓ/ha. Diflubenzuron applied during the first instar may provide foliage protection as well as population reduction. The lower but more concentrated dose should be as effective as the standard rate at 4.7 ℓ/ha.

Larval reduction in blocks treated with fenitrothion were sampled five and six days after the second treatment. Populations were

reduced by 60% for fenitrothion (Folethion Technical) in oil (used for operational sprays) and 54% for the more concentrated water-based formulation (Table 4). At the pupal stage population reduction was 99% for the oil-based and 92% for the water-based formulation. In both blocks larvae died 8 to 10 days after the last spray when many larvae were in the early fourth instar. About half the larvae that survived to the pupal stage also emerged as adults, which was similar to percent emergences in the controls. The percent of the pre-spray larval population reaching the adult stage was essentially the same for all four treatment blocks.

Fenitrothion affected looper larvae in one unusual way. Larvae in the sprayed plots became moribund two days after each treatment, then recovered, but then died after about 10 days. Within three to four days larvae on trees in the treated blocks appeared normal again and subsamples taken at that time showed no further reduction from post-spray counts. However, by the 10th day the number of larvae in the spray blocks were greatly reduced. Moribund larvae collected two days of the spray taken into the laboratory and fed on unsprayed foliage recovered. Therefore post-spray sampling of hemlock looper larvae should be delayed at least 10 days after treatment to obtain total larval reduction data caused by the fenitrothion treatment.

Foliage Protection

Proportion of foliage saved, based on tree estimates from the ground, was lower for diflubenzuron blocks than for the fenitrothion blocks (Table 4). Diflubenzuron at the standard dose of 4.7 ℓ/ha showed

about 40% foliage protection. Foliage protection by fenitrothion was about 60% which is considered adequate protection for aerial applications. Populations on the diflubenzuron blocks were nearly double those in the fenitrothion blocks, and general defoliation surrounding the Dimilin blocks was higher. The early application planned should have improved foliage protection of diflubenzuron treatments. Such treatments should be tested.

CONCLUSIONS

The hemlock looper appears to require two applications of chemicals to achieve acceptable control when spraying begins the first few days in July. The hatching period was more prolonged in 1986 than in 1985 but almost all larvae received two applications because the sprays were delayed.

The lower and more concentrated dose of diflubenzuron at 2.5 ℓ/ha provided population control only slightly below that of the same dose in 4.7 ℓ/ha, and is a satisfactory formulation. Foliage protection was poor in 1986, because of the delay in spraying and because of the damage done by the high number of early-instar larva. Since diflubenzuron persists on the the foliage, earlier applications should be tried.

Both the oil-based formulation of fenitrothion at 210 g ai/ha and the water-based formulation at 180 g ai/ha provided adequate control and foliage protection. Both gave better control than the same rate (210 g ai/ha) did in 1985. The 1986 results are similar to those of other studies, and the poor population reduction of only 74% achieved in

1985 seems to have been the exception. Either formulation of fenitrothion could be used and differences in residual effects, spray cloud behavior and ease of handling will determine which formulation is preferred for hemlock looper control. The greater probability of evaporation affecting water-base formulations may prevent its use in large aircraft which fly higher above the canopy than small aircraft.

Table 1. Formulations and spray details of insecticides tested against the hemlock looper in Newfoundland in 1986.

Name of concentrate	Rate of application (ℓ/ha)	Area sprayed (ha)	Active ingredient per ha (g)	Total vol. applied (ℓ)	Amount of Concentrate in mix	Vol. of Dye (ℓ)	Vol. of Emulsifier (ℓ)	Vol. of diluent added (ℓ)	Type of diluent
Diflubenzuron									
Dimilin 25 wp	4.7	51	70	240	14.3 kg	1.20[a]	-	240	water
Dimilin 25 wp	2.5	51	70	127	14.3 kg	1.20[a]	-	127	water
Fenitrothion									
Sumithion 20 F	0.9	30	180	27	27 ℓ	1.1	-	0	-
Folethion Technical	1.5	30	210	45	4.9 ℓ	0.9[b]	18[c]	22.1	ID 585 oil

[a] Rhodamine B.

[b] Automate Red B.

[c] Cyclosol 63.

Table 2. Number of hemlock looper larvae by instar and date near Gallants, Newfoundland in 1986.

Date	% Instar				Total number in sample
	1st	2nd	3rd	4th	
June 16	100	0	0	0	2 224
June 19	100	0	0	0	1 675
June 23	100	0	0	0	2 914
June 26	90.6	9.4	0	0	2 384
June 27/28	77.4	22.6	0	0	5 793
July 2	48.1	51.9	0	0	12 125
July 6/7	21.2	78.8	0	0	8 276
July 9	19.5	77.2	3.3	0	6 935
July 12/13	10.3	75.6	14.1	0	14 537
July 17	3.9	31.1	65.0	0	11 479
July 22/23	2.5	22.5	73.9	1.1	10 133

Table 3. Application rates, time of spray and weather parameters for treatments against the hemlock looper near Gallants, Newfoundland in 1986.

	Block D1 diflubenzuron application		Block D2 diflubenzuron application		Block S1 fenitrothion application		Block S2 fenitrothion application	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Base	water	water	water	water	water	water	oil	oil
Rate ℓ/a	2.5	2.5	4.7	4.7	0.9	0.9	1.5	1.5
Date applied	July 7	July 14	July 6	July 13	July 8	July 16	July 8	July 17
Time	20:35	20:55	20:45	20:50	06:45	20:10	07:40	20:55
Ave. temp °C	13	12	12	11	9	12	11	13
Ave. % RH	85	85	86	95	94	94	89	88
Hrs. to next rain	22	20	46	44	12[c]	110	12[c]	86
Ave. wind speed (km/h)	1.6	1.0	3.0	3.2	1.0	1.0	1.0	1.2
Range in wind speed	0-3	0-3	0-6[b]	2-4	0-2	0-2	0-2	0-3
Wind direction	NNW	NE	NW-NNW	NW	ESE	SSW	SW	SW
Air stability[a]	↓	↔	↓	↓	↔	↔	↔	↓

a ↓ = inversion, ↑ = lapse, ↔ = neutral.

b Higher wind gust during first two swaths only.

c Very light drizzle only, no measurable precipitation.

Table 4. Results of aerial application of insecticides against the hemlock looper in Newfoundland in 1986.

Treatment	No. applications and dosage (g ai/ha)	Volume applied (ℓ/ha)	Average pre-spray population per sample	% Population reduction[a]		% Moth emergence of survivors to pupal stage	% Foliage saved[b]
				Post-spray larvae	Pupae		
Dimilin	2 x 70	2.5 (water)	185	26	90	7	0
Control	-		202			70	
Dimilin	2 x 70	4.7 (water)	269	62	93	18	40
Control	-		202			70	
Sumithion 20F	2 x 180	0.9 (water)	86	54	92	53	65
Control	-		107			55	
Sumithion Tech.	2 x 210	1.5 (oil)	118	60	99	53	59
Control	-		107			55	

[a] Calculated with Abbott's formula.

[b] $\frac{\text{Defoliation in controls - defoliation in plot}}{\text{defoliation in controls.}}$

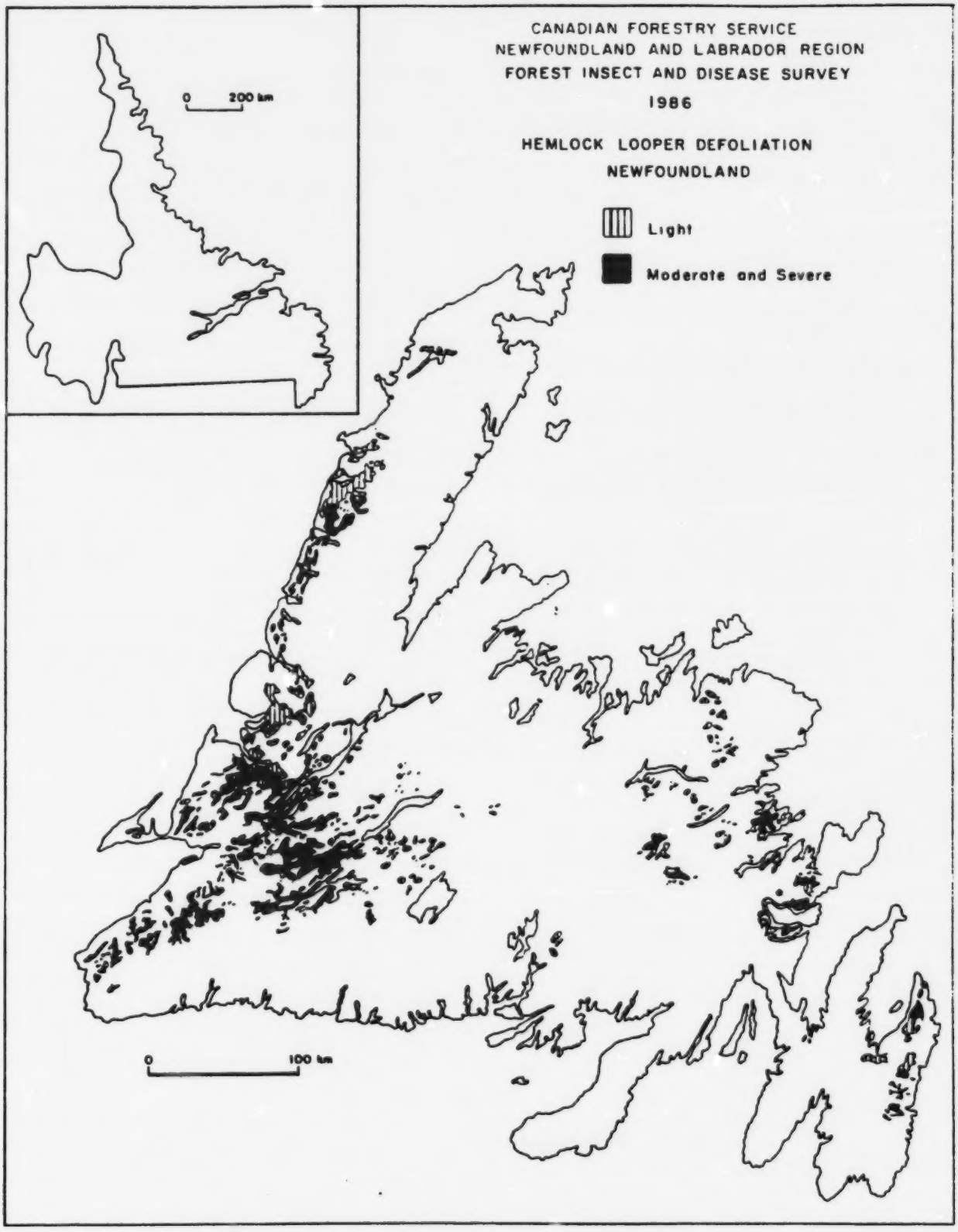

Figure 1. Areas of hemlock looper defoliation in Newfoundland in 1986.

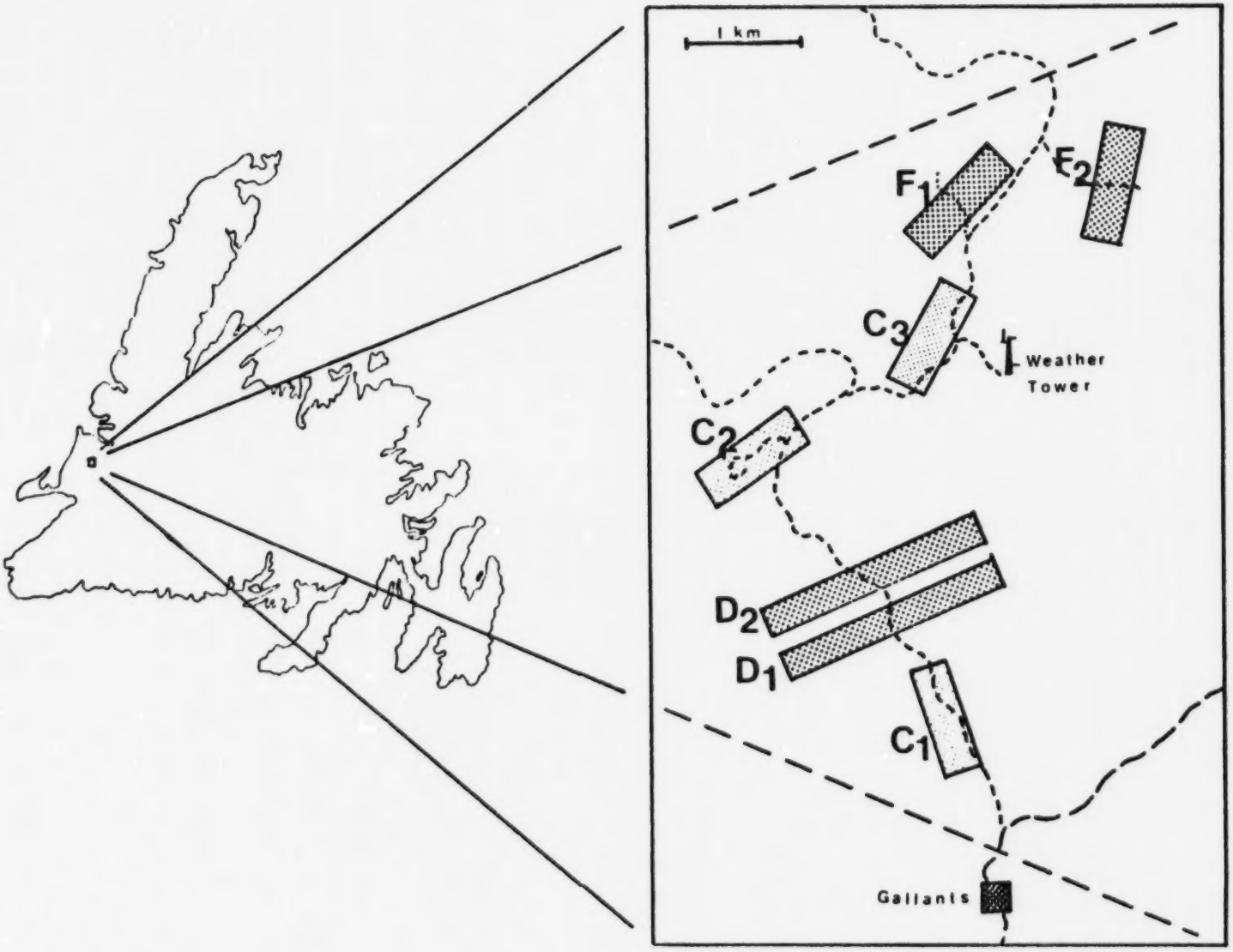

Figure 2. Experimental area for testing effectiveness of insecticides against the hemlock looper in Newfoundland in 1986.

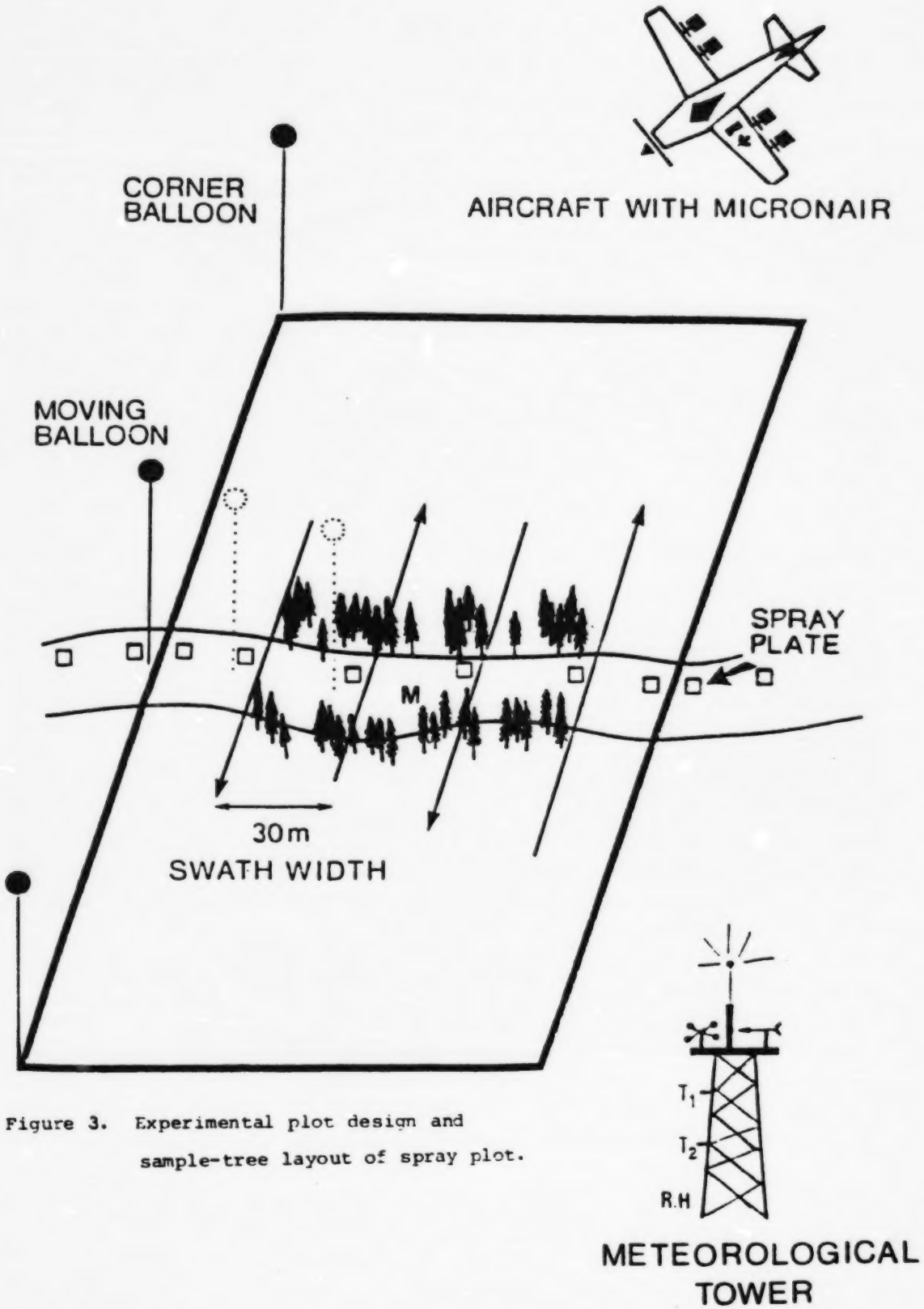

Figure 3. Experimental plot design and sample-tree layout of spray plot.

Figure 4. Grumman AgCat used in experimental sprays against the hemlock looper in Newfoundland in 1986.

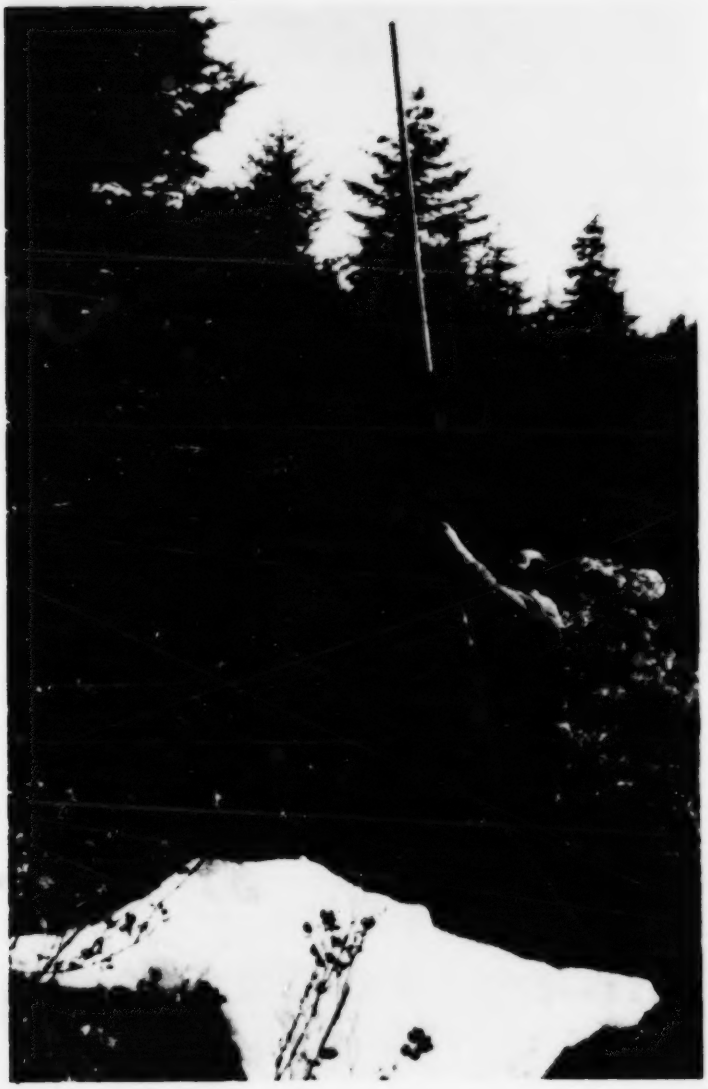

Figure 5. Dislodging hemlock looper larvae over a ground cloth.

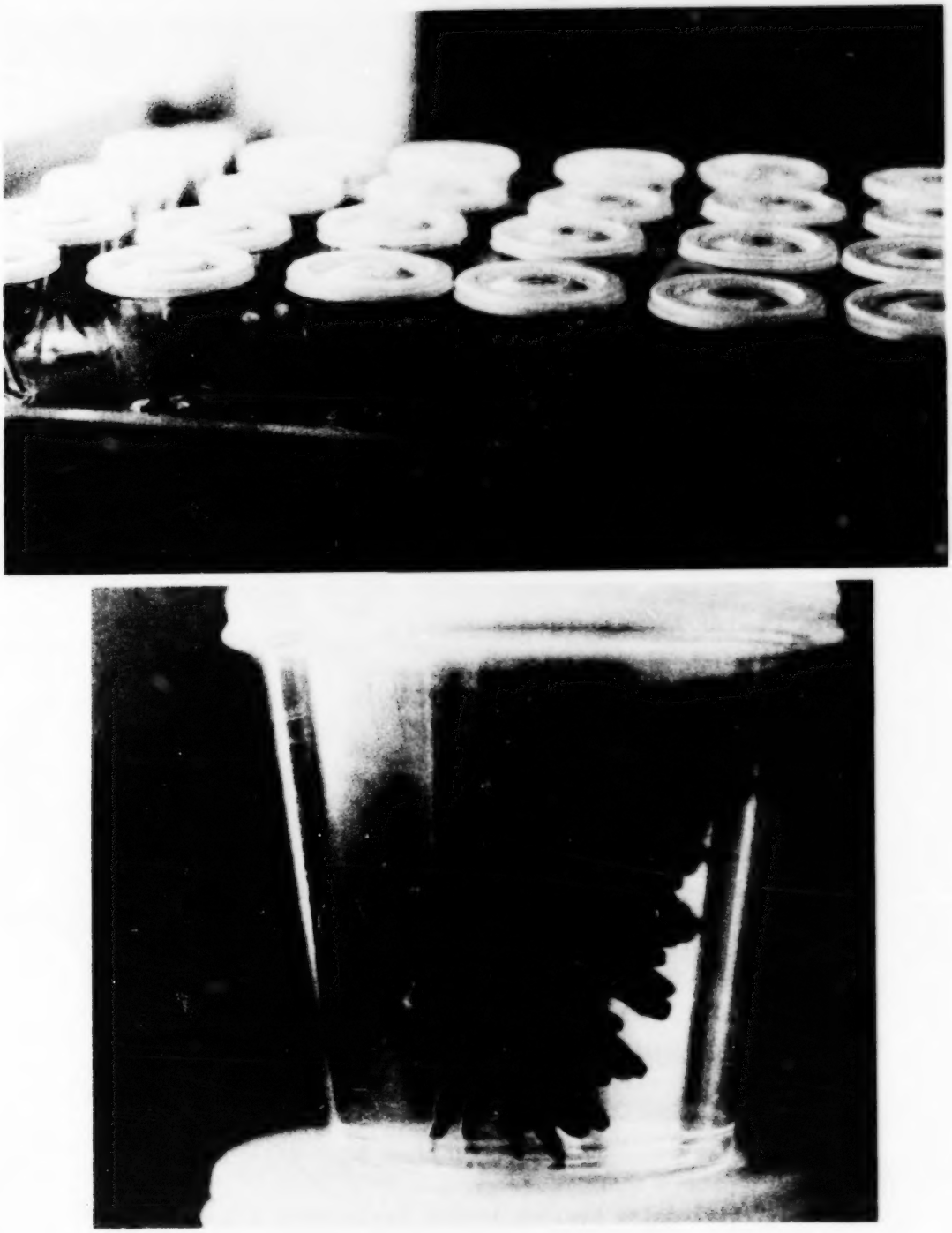

Figure 6. Rearing hemlock looper larvae in plastic containers.

Figure 7. Pupal trap for hemlock looper on the bole of a balsam fir.

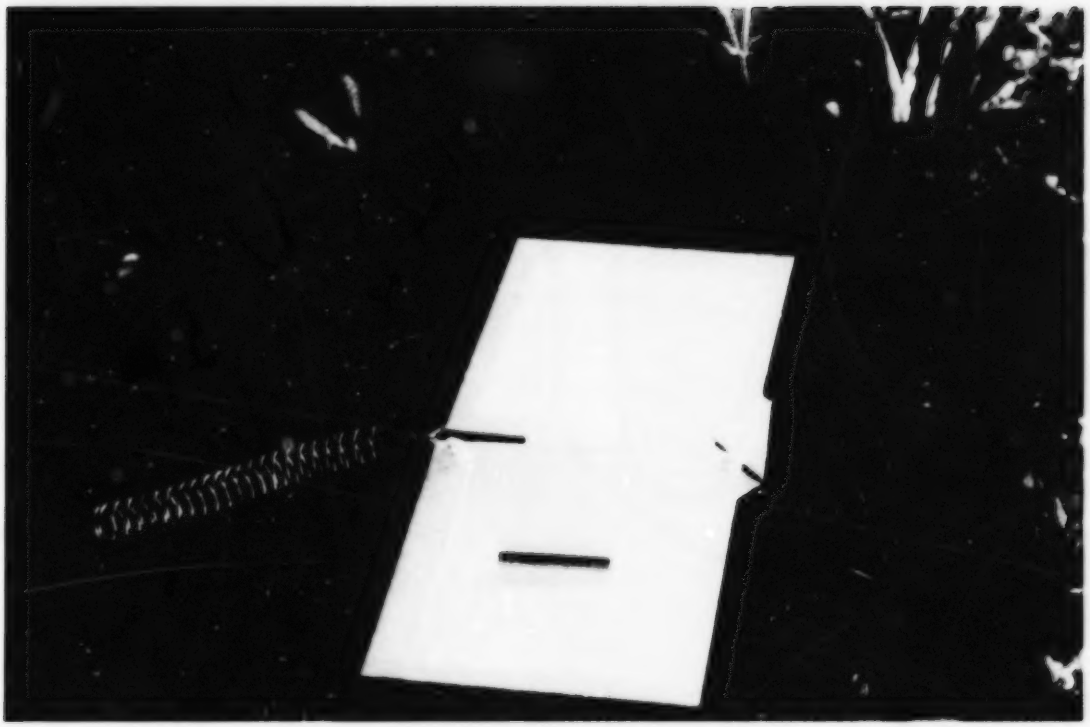

Figure 8. Ground unit to measure spray deposit.

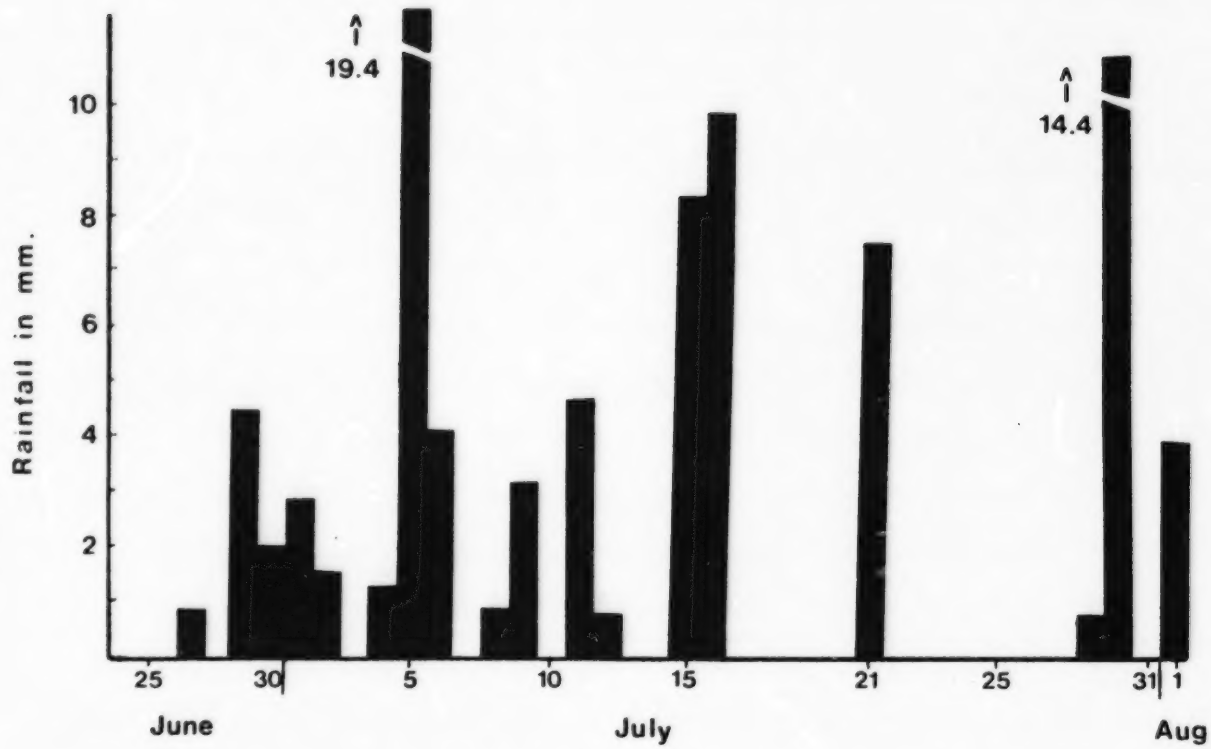

Figure 9. Daily rainfall in July 1986 at the experimental blocks near Gallants, Newfoundland.

LITERATURE CITED

Abbott, W.S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Ent. 18:265-267.

Carroll, W.J. 1956. History of the hemlock looper, Lambdina fiscellaria fiscellaria (Guen.) (Lepidoptera: Geometridae) in Newfoundland and notes on its biology. Can. Ent. 83:587-599.

Clarke, L.J. and G.C. Carew. 1985. Forest insect and disease conditions in Newfoundland and Labrador in 1984. Env. Can., Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rep. N-X-229, St. John's, Nfld. 31 pp.

Clarke, L.J. and G.C. Carew. 1986. Forest insect and disease conditions in Newfoundland and Labrador in 1985. Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rep. N-X-241, St. John's, Nfld. 33 p.

Clarke, L.J and G.C. Carew. 1987. Forest insect and disease conditions in Newfoundland and Labrador in 1986. Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rep. N-X-241, St. John's, Nfld. 36 p.

Crummey, H. 1986. Information on Newfoundland's 1985 operational spray program against eastern hemlock looper (Lambdina fiscellaria fiscellaria (Guen.)). Can. For Serv., Rep. 13th Ann. For. Pest Control Forum, Ottawa, Ont., Nov. 19-21, 1985, pp. 70-75 (unpublished).

Crummey, H. 1987. Insect control program in Newfoundland in 1986. Can. For. Serv., Rep. 14 Ann. For. Pest Control Forum, Ottawa, Ont., Nov. 18-20, 1986, pp. 37-46 (unpublished).

Delaney, B.B. and S.M. Osmond. 1975. Manual for the design for the management inventory, Newfoundland Dept. For. and Agric., For. Inventory Div., St. John's, Nfld. 35 pp.

Fleming, R. and A. Retnakaran. 1985. Evaluating single treatment data using Abbott's formula with reference to insecticides. J. Econ. Ent. 78:1179-1181.

Otvos, I.S. 1974. A collecting method for pupae of Lambdina fiscellaria fiscellaria (Lepidoptera: Geometridae). Can. Ent. 106:329-331.

Otvos, I.S., L.J. Clarke and D.S. Durling. 1979. A history of recorded eastern hemlock looper outbreaks in Newfoundland. Env. Can., For. Serv., Newfoundland For. Res. Centre, Inf. Rep. N-X-179. St. John's, Nfld. 46 pp.

Randall, A.P. 1980. A simple device for collecting aerial-spray deposits from calibration trials and spray operations. Environ. Can., Can. For. Serv., Bi-mon. Res. Notes 36(5):23.

Raske, A.G., A. Retnakaran, R.J. West, J. Hudak, K.P. Lim. 1986. The effectiveness of Bacillua thuringiensis, Dimilin, Sumithion and Matacil against the Hemlock Looper, Lambdina fiscellaria fiscellaria, in Newfoundland in 1985. Can. For. Serv., Newfoundland For. Res. Centre, Inf. Rep. N-X-238, St. John's, Nfld. 89 pp.

Sundaram, A., A. Retnakaran, A.G. Raske and R.J. West. 1987a. Effect of application rate on droplet size spectra and deposit characteristics of Dimilin spray mixtures in an aerial trial. Pesticide Formulations and Application Systems, Seventh Vol. ASTM STP 968, Amer. Soc. for Testing and Materials, Philadelphia PA, pp. 104-115.

Sundaram, K.M.S., A.G. Raske, A. Retnakaran, R.J. West and J. Hudak. 1987b. Formulation properties, droplet size spectra, ground deposits and foliar residue of aminocarb and fenitrothion in flushed and one year old balsam fir needles following aerial application in Newfoundland forests. Pesticide Science 21:105-118.

West, R.J., A.G. Raske, A. Retnakaran and K.P. Lim. 1987. Efficacy of various Bacillus thuringiensis Berliner var. kurstaki formulations and dosages in the field against the hemlock looper, Lambdina fiscellaria fiscellaria (Guen.)(Lepidoptera: Geometridae) in Newfoundland. Can. Ent. 119:449-458.